ISSN 1809-127X (online edition)

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LISTS OF SPECIES

Plantae, aquatic, amphibian and marginal species, Massaguaçu River Estuary, Caraguatatuba, São Paulo, Brazil

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ABSTRACT: Estuaries are the buffer zones between river and ocean. Because they are under strong tidal influence, their flora must be able to cope with salinity and flooding stress. In the present study we combined results from two surveys we performed in the Massaguaçu River Estuary (23°37'20" S, 54°21'25" W), with the objective of providing a full inventory of its aquatic, amphibian, and marginal flora. We reported 102 species among 77 genera and 47 families, including six Pteridophyta species.

INTRODUCTION

Estuaries (from Latin *aestus*: tide and *arium*: receptacle) are the buffer zones between river and ocean. Thus, they are under strong tidal influence (Wolanski 2007). When river and ocean are permanently connected (regular estuaries), this influence happens continuously. However, it is common, particularly in tropical regions, estuaries in which the ocean builds a sandbar (that breaches from time to time) that seals their connection with a river (Miranda *et al.* 2002). In these cases, the ocean-river connection is intermittent (irregular estuaries) and tidal influence is limited. Regardless of the connection characteristics, estuaries are environments closely related to tide cycles, and therefore, estuarine plants must be able to cope with salinity and flooding. Furthermore, in coastal environments salt can reach plants and non-flooding soil through salt spray (Boyce 1954; Wells and Shunk 1938) and tidal salinization of the aquifer (Werner and Lockington 2006) so, even plants above the estuarine brackish water level are exposed to salt stress.

In irregular estuaries, breaching cycles are frequently unpredictable events (Costa *et al.* 2003). This leads to an unpredictability of tidal influence, and therefore, to an inconstancy of saline and flooding conditions. This increases the importance of stochastic events in plant composition, and irregular estuaries are expected to present several opportunistic amphibian species in addition to their aquatic flora.

Plant zonation along salinity and flooding gradients is one of the main gaps in the knowledge about tidal environments (Crain *et al.* 2004), and irregular tropical estuaries are particularly poorly studied (Costa *et al.* 2003). Furthermore, as most studies regarding that matter focus only on few species (Castillo *et al.* 2000; Costa *et al.* 2003; Emery*et al.* 2001; Touchette, 2006), a full estuary species inventory is rarely published. Therefore, there is a great demand for species list in these environments. Here we present a species list of aquatic, amphibian, and marginal flora from the Massaguaçu River Estuary, Caraguatatuba, state of São Paulo, Brazil.

MATERIALS AND METHODS

Study site

Massaguaçu River Estuary (23°37'20" S, 54°21'25" W) is an irregular estuary. Its sandbar breaches several times every year, with cycles that range from a few days to more than one month (Figure 1). The duration of the connection with the ocean also varies, from one tidal cycle to more than two weeks. The estuary is located in a region with humid tropical climate (*af*), with mild winter, rain in all months and no biological dry season (Koeppen 1948).

The estuary left margin is a sand line that is now disturbed. This margin still presents riparian vegetation in almost all its extension. The right margin is better preserved, and is a lowland Atlantic forest in different degrees of preservation. The right margin is L shaped (Figure 1 - white line), with the small leg exposed to the ocean and the long leg protected from it by the sand line.

The estuary presents five major macrophytes banks (Figure 1 - Mb), with dense formations of both aquatic and amphibian plants. The estuary is under crescent pressure from the growing nearby human neighborhoods. However, to the best of our knowledge, there is no history of main direct disturbance in the last 30 years. The sandbar breaching is a natural event, but artificial breaching is becoming more often, and the effects of this practice on the estuary flora are uncertain.

Data collection

The species list in this work came from two surveys that we performed in the estuary. The first focused on the riparian vegetation of the right margin. For that, we searched the margin collecting the closest tree (diameter of ≥ 5cm at 1.5m high) to the maximum water line level. In the second, we surveyed the flora inside the estuary. We randomly placed 400 plots (5x5m, 25m^2) in the five main

macrophytes banks (80 per bank), and collected all species (including Pteridophyta and rooted lianas) in the plot. Species were classified according to APG III (APG 2009). Voucher specimens were deposited in the Herbarium of the Botanical Department, Federal University of São Carlos (HUFSCar).

Results and Discussion

We reported 102 species among 77 genera and 47 families, including six Pteridophyta species (Table 1, Figures 2-6). The richest Angiosperm families were Cyperaceae (14 species), Fabaceae (9), Poaceae (8), Primulaceae (6), Onagraceae (5) and Melastomataceae, Myrtaceae and Polygonaceae (4). Thirty-nine families were represented by trees or less species (Figure 7). As far as we know the present work is the first species inventory for an irregular estuary in Brazil.

Its flora seems to be similar to the flora of other irregular estuaries we have visited in the same region. However, to the best of our knowledge there are no studies regarding that matter, and this information needs to be confirmed by formal studies. Regular estuaries in the same longitude usually present mangrove vegetation. This vegetation is related to wide tide ranges, and is mainly characterized by few trees (*Rhizophora mangle* L., *Laguncularia racemosa* (L.) C.F. Gaertn., *Avicennia* sp.) and herbaceous (*Spartina* sp., *Hibiscus* sp. and *Acrostichum* sp.) species (Silva *et al.* 2005). Thus, when compared to this very low species richness (Vannucci 2001), the number of species of Massaguaçu River Estuary is strictly higher.

The reasons for those differences are not completely clear, and there is a great demand for studies regarding plant zonation and species inventories in tropical estuaries. It has been proposed that environmental unpredictability and the wide variation in the hydrological condition lead to a lack of stress persistence (Costa *et al.* 2003). The unpredictability prevents the competitive balance to be reached (Russell *et al.* 1985), and allows species to occur in wide zones along the gradient (Baldwin and Mendelssohn 1998). The intermittent flooding stress allows riparian species to occur in the macrophyte banks, as several non-aquatic plants can cope with moderate sporadic flooding (Kozlowski 1997). Although we have not performed a formal sampling of the riparian herbaceous flora, field observations support that the opposite is also true, and several macrophytes species can live in non-flooded conditions.

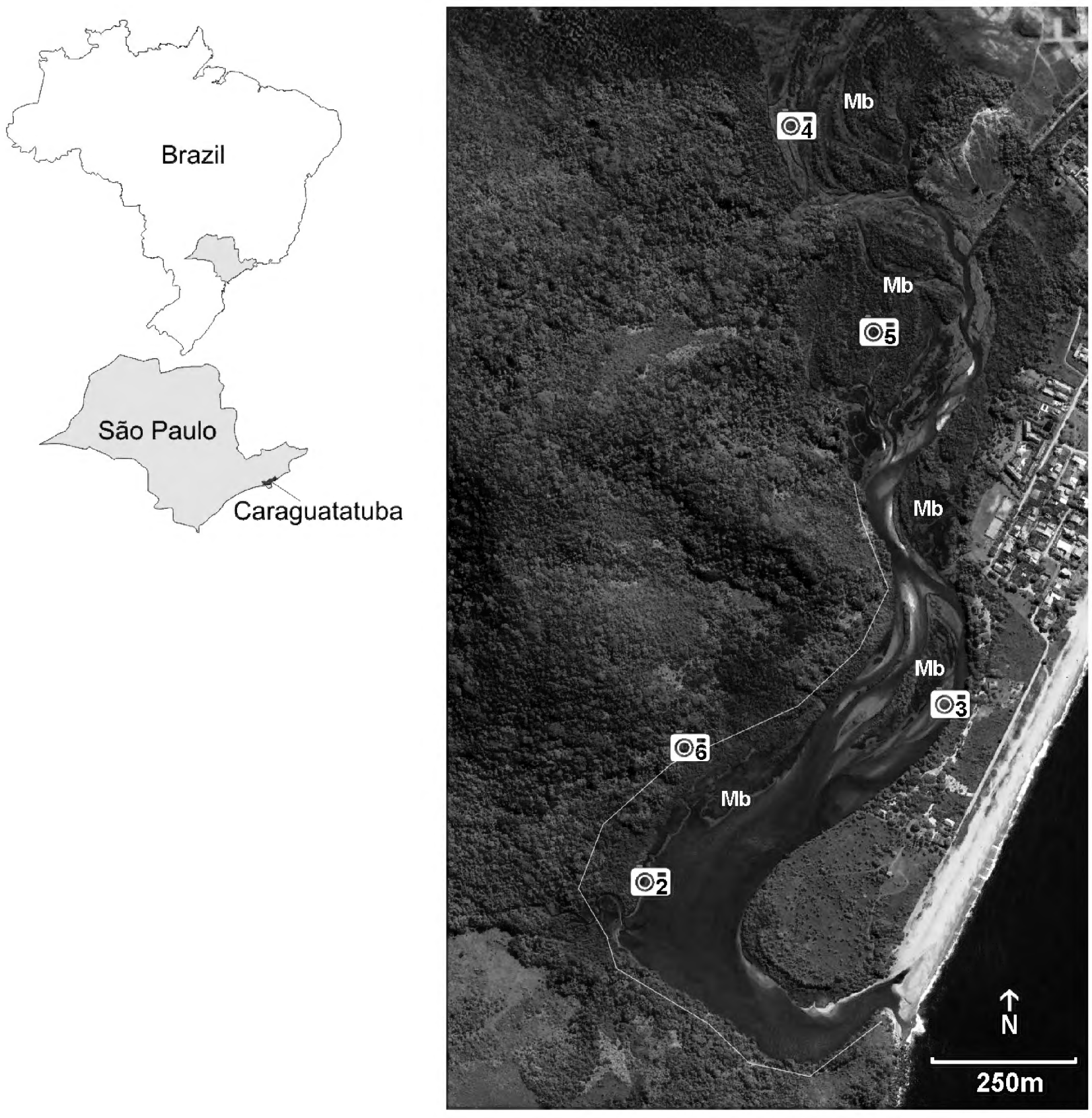

Figure 1. Massaguaçu River Estuary regional location and aerial image. Mb= main macrophyte banks. White line = Riparian vegetation sampling path. Camera icons= approximate location where the photographs (Figure 2-6) were taken.

Figure 2. Area near sandbar, with dense formations of *Crinum americanum* L.

Figure 3. Area in an intermediary position in the estuary, just after the mouth closure, showing recently flooded formations of *Bacopa monnieri* (L.) Pennell and *Eleocharis minima* Kunth. In back plane, *Crinum americanum* L. and *Acrostichum danaeifolium* Langsd. and Fisch. In the back, tree species with several individuals of *Annona glabra* L,. *Dalbergia ecastaphyllum* (L.) TAUB., and *Mimosa bimucronata* (DC.) Kuntze.

Figure 4. Region away from sandbar, with formations dominated by *Rhynchospora corymbosa* (L.) Britton, *Eleocharis interstincta* (Vahl) Roem. and Schult., *Scleria mitis* P.J. Bergius and *Scleria latifolia* Sw. In back plane, the arboreal compound, manly *Tabebuia cassinoides* (Lam.) D.C., *Annona glabra* L. and *Calophyllum brasiliense* Cambess.

Figure 5. Higher plots, subjected to sporadic flooding, with arboreal stratum and several amphibian herbaceous species.

Figure 6. General view of estuary right margin.

Table 1. Species inventory of aquatic, amphibian, and marginal flora of Massaguaçu River Estuary, Caraguatatuba, São Paulo, Brazil. H = herb; L = liana; T = tree; Mb = macrophyte banks; R = riparian, Both = both.

DIVISION/FAMILY	SPECIES	LIFE FORM	LOCATION
PTERIDOPHYTA			
Blechnaceae	*Blechnum serrulatum* Rich.	H	Mb
Dryopteridaceae	*Cyclodium meniscioides* (Willd.) C.Presl	H	Mb
Lygodiaceae	*Lygodium volubile* Sw.	H	Mb
Polypodiaceae	*Serpocaulon triseriale* (Sw.) A. R.	H	Mb
Pteridaceae	*Acrostichum danaeifolium* Langsd. and Fisch	H	Mb
Thelypteridaceae	*Thelypteris interrupta* (Willd.) K.Iwats.	H	Mb
ANGIOSPERMAE			
Alismataceae	*Sagittaria montevidensis* Cham. and Schltdl.	H	Mb
Amaranthaceae	*Alternanthera philoxeroides* (Mart.) Griseb.	H	Mb
Amaryllidaceae	*Crinum americanum* L.	H	Mb
Anacardiaceae	*Tapirira guianensis* Aubl.	T	R
Annonaceae	*Annona glabra* L.	T	Both
Annonaceae	*Guatteria australis* A. St.-Hil.	T	R
Apiaceae	*Centella asiatica* (L.) Urb.	H	Mb
Apocynaceae	*Forsteronia* sp.	L	Mb
Aquifoliaceae	*Ilex brevicuspis* Reissek	T	R
Aquifoliaceae	*Ilex* sp.	T	R
Aquifoliaceae	*Ilex theezans* Mart.	T	R
Arecaceae	*Astrocaryum aculeatissimum* (Schott) Burret	T	R
Arecaceae	*Syagrus romanzoffiana* (Cham.) Glassman	T	Both
Asteraceae	*Eremanthus erythropappus* (DC.) MacLeish	T	R
Asteraceae	*Mikania hastato-cordata* Malme	L	Mb
Asteraceae	*Stifftia fruticosa* (Velloso) D.J.N. Hind and Semir	T	R
Berberidaceae	*Berberis laurina* Thunb.	T	R
Bignoniaceae	*Tabebuia cassinoides* (Lam.) DC.	T	Mb
Boraginaceae	*Cordia curassavica* (Jacq.) Roem. and Schult.	H	R
Bromeliaceae	*Aechmea distichantha* Lem.	H	Mb
Calophyllaceae	*Calophyllum brasiliense* Cambess.	T	Both
Clusiaceae	*Clusia criuva* Cambess.	T	Both
Clusiaceae	*Garcinia gardneriana* (Planch.and Triana) Zappi	T	Both
Commelinaceae	*Commelina schomburgkiana* Klotzsch.	H	Mb
Convolvulaceae	*Ipomoea cairica* (L.) Sweet	L	Mb
Costaceae	*Costus arabicus* L.	H	Mb
Cyperaceae	*Calyptrocarya longifolia* (Rudge) Kunth	H	Mb
Cyperaceae	cf. *Rhynchospora* sp.	H	Mb
Cyperaceae	*Cyperus* sp.	H	Mb
Cyperaceae	*Eleocharis flavescens* (Poir.) Urb.	H	Mb
Cyperaceae	*Eleocharis interstincta* (Vahl) Roem. and Schult.	H	Mb
Cyperaceae	*Eleocharis minima* Kunth	H	Mb
Cyperaceae	*Eleocharis montana* (Kunth) Roem. and Schult.	H	Mb
Cyperaceae	*Fuirena umbellata* Rottb.	H	Mb
Cyperaceae	*Rhynchospora* cf. *holoschoenoides* (Rich.) Herter	H	Mb
Cyperaceae	*Rhynchospora corymbosa* (L.) Britton	H	Mb
Cyperaceae	*Schoenoplectus californicus* (C.A. Mey.) Soják	H	Mb
Cyperaceae	*Scleria latifolia* Sw.	H	Mb
Cyperaceae	*Scleria mitis* P.J. Bergius	H	Mb
Cyperaceae	undetermined	H	Mb
Euphorbiaceae	*Pera glabrata* (Schott) Poepp. ex Baill.	T	Both
Fabaceae	*Abarema brachystachya* (DC.) Barneby and J.W. Grimes	H	Mb
Fabaceae	*Andira fraxinifolia* Benth.	T	R
Fabaceae	*Dalbergia ecastaphyllum* (L.) Taub.	T	Mb

Table 1. ***Continued.***

DIVISION/FAMILY	SPECIES	LIFE FORM	LOCATION
Fabaceae	*Erythrina crista-galli* L.	T	R
Fabaceae	*Inga minutula* (Schery) T.S. Elias	T	R
Fabaceae	*Machaerium uncinatum* (Vell.) Benth.	T	R
Fabaceae	*Mimosa bimucronata* (DC.) Kuntze	T	R
Fabaceae	*Mysanthus uleanus* (Harms) G.P. Lewis and A. Delgado	T	R
Fabaceae	*Zollernia ilicifolia* (Brongn.) Vogel	T	R
Lauraceae	*Ocotea oppositifolia* S. Yasuda	T	R
Loganiaceae	*Spigelia* sp.	H	Mb
Malpighiaceae	*Stigmaphyllon ciliatum* (Lam.) A. Juss	L	Mb
Malvaceae	*Eriotheca pentaphylla* (Vell.) A. Robyns	T	Mb
Malvaceae	*Hibiscus pernambucensis* Arruda	T	Mb
Melastomataceae	*Clidemia* cf. *bullosa* DC.	H	Mb
Melastomataceae	*Miconia cinnamomifolia* (DC.) Naudin	T	R
Melastomataceae	*Miconia fallax* DC.	T	R
Melastomataceae	*Miconia prasina* (Sw.) DC.	T	R
Menyanthaceae	*Nymphoides* sp.	H	Mb
Myrtaceae	*Eugenia umbelliflora* L.	T	Both
Myrtaceae	*Eugenia uniflora* L.	T	Both
Myrtaceae	*Myrcia splendens* (Sw.) DC.	T	R
Myrtaceae	*Psidium cattleianum* Sabine	T	R
Nyctaginaceae	*Guapira opposita* (Vell.) Reitz	T	R
Moraceae	*Brosimum guianense* Huber ex Ducke	T	R
Moraceae	*Ficus* cf. *enormis* (Mart. ex Miq.) Mart.	T	R
Nymphaeaceae	*Nymphaea caerulea* Savigny	H	Mb
Onagraceae	*Ludwigia elegans* (Cambess.) H. Hara	H	Mb
Onagraceae	*Ludwigia erecta* (L.) H. Hara	H	Mb
Onagraceae	*Ludwigia filiformis* (Micheli) Ramanoorthy	H	Mb
Onagraceae	*Ludwigia hyssopifolia* (G. Don) Excell	H	Mb
Onagraceae	*Ludwigia octovalvis* (Jacq.) P.H.Raven	H	Mb
Plantaginaceae	*Bacopa monnieri* (L.) Wettst.	H	Mb
Poaceae	*Acroceras zizanioides* (Kunth) Dandy	H	Mb
Poaceae	*Axonopus* sp.	H	Mb
Poaceae	*Brachiaria mutica* (Forssk.) Stapf	H	Mb
Poaceae	*Echinochloa polystachya* (Kunth) Hitchc.	H	Mb
Poaceae	*Hymenachne amplexicaulis* (Rudge) Ness	H	Mb
Poaceae	*Panicum* sp.1	H	Mb
Poaceae	*Panicum* sp.2	H	Mb
Poaceae	*Paspalum* sp.	H	Mb
Polygonaceae	*Polygonum ferrugineum* Wedd.	H	Mb
Polygonaceae	*Polygonum hydropiperoides* Michx.	H	Mb
Polygonaceae	*Polygonum meisnerianum* Cham. and Schltdl.	H	Mb
Polygonaceae	*Coccoloba* sp.	T	R
Primulaceae	*Myrsine coriacea* (Sw.) R. Br. ex Roem. and Schult.	T	Both
Primulaceae	*Myrsine guianensis* (Aubl.) Kuntze	T	Both
Primulaceae	*Myrsine parvifolia* A. DC.	T	Both
Primulaceae	*Myrsine umbellata* (Mart.) Mez	T	Both
Primulaceae	*Myrsine venosa* A. DC.	T	Both
Primulaceae	*Myrsine* sp.	T	Both
Rubiaceae	*Tocoyena bullata* (Vell.) Mart.	T	Mb
Sapindaceae	*Cupania* cf. *oblongifolia* Mart.	T	R
Typhaceae	*Typha domingensis* Pers.	H	Mb
Urticaceae	*Coussapoa microcarpa* (Schott) Rizzini	T	Both

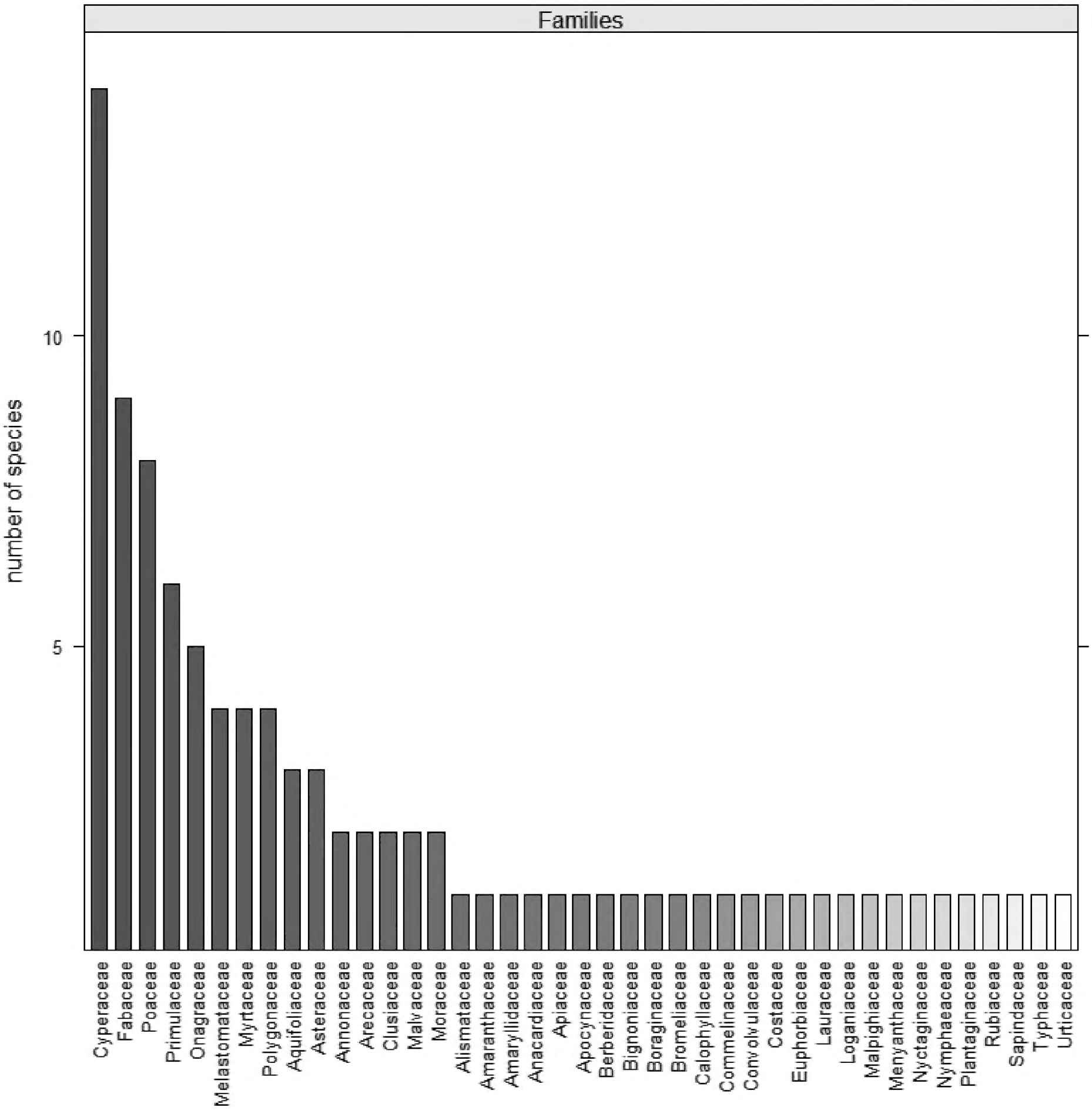

Figure 7. Frequency histogram of families with number of Angiospermae species of aquatic, amphibian, and marginal flora of Massaguaçu River Estuary, Caraguatatuba, state of São Paulo, Brazil.

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Received: December 2010
Last Revised: January 2011
Accepted: February 2011
Published online: March 2011
Editorial responsibility: Frederico Augusto Guimarães Guilherme